(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 February 2002 (21.02.2002)

PCT

(10) International Publication Number
WO 02/14572 A1

(51) International Patent Classification[7]: C23C 2/24, 2/36, 2/40, 6/00

(21) International Application Number: PCT/SE01/01735

(22) International Filing Date: 10 August 2001 (10.08.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0002890-2 11 August 2000 (11.08.2000) SE

(71) Applicants (*for all designated States except US*): **POHANG IRON AND STEEL COMPANY LTD** [KR/KR]; Nam-Ku Pohang 790-785 (KR). **ABB AB** [SE/SE]; S-721 83 Västerås (SE).

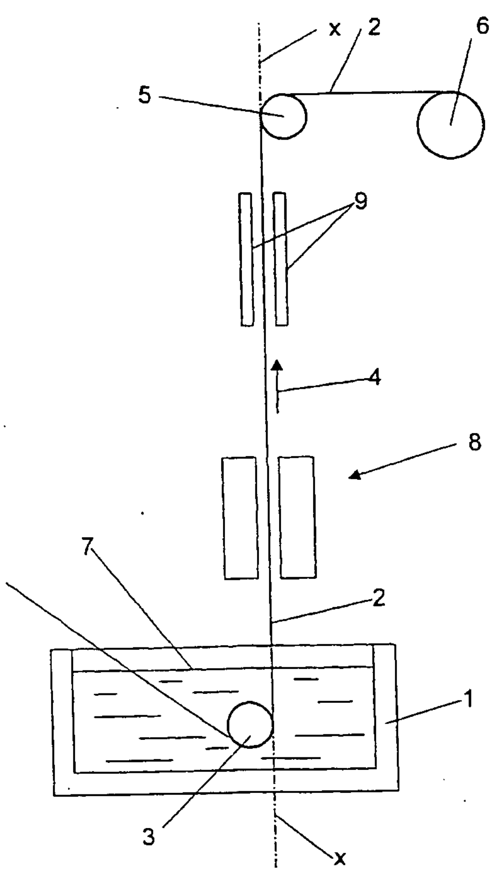
(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **RYDHOLM, Bengt** [SE/SE]; Brunnbygatan 68, S-722 23 Västerås (SE). **KARLSSON, Sven** [SE/SE]; Solvagnsgatan 12, S-723 51 Västerås (SE). **HALLBÄCK, Magnus** [SE/SE]; Svartvikisslingan 27, S-167 38 Bromma (SE). **TALLBÄCK, Göte** [SE/SE]; Bandygatan 12, S-722 40 Västerås (SE). **ERIKSSON, Per, L.** [SE/SE]; Lavendelvägen 13, S-721 45 Västerås (SE). **PARK, Jeong-Real** [KR/KR]; Whamok Apt. 10-203, Taejam-dong, Kam-Ku (KR).

(74) Agents: **BERGLUND, Stefan** et al.; Bjerkéns Patentbyrå KB, Östermalmsgatan 58, S-114 50 Stockholm (SE).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EC, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

[Continued on next page]

(54) Title: A METHOD FOR CONTROLLING THE THICKNESS OF A GALVANISING COATING ON A METALLIC OBJECT



(57) Abstract: The invention refers to a method for controlling the thickness of a galvanising coating on a metallic object (2). The coating is applied by continuous transportation of the object from an arrangement (1) for depositing a molten metal onto the object. The metallic object (2) is transported from said arrangement in a transportation direction along a transportation path (4) including a plane (x). Excessive molten metal is wiped off from the object by applying a magnetic force onto the object (2). Moreover, the position of the object (2) is stabilised with respect to the plane (x) by means of an electromagnetic stabilising device.

WO 02/14572 A1

(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A method for controlling the thickness of a galvanising coating on a metallic object

THE BACKGROUND OF THE INVENTION AND PRIOR ART

The present invention refers to a method for controlling the thickness of a galvanising coating on a metallic object, said coating being applied by continuous transportation of the object through an arrangement for depositing a molten galvanising metal onto the object.

Such a method is particularly advantageous in continuous galvanising of a steel strip. The present invention will hereinafter be described with reference to such an application. However, it is to be noted that the invention is also applicable to galvanising of other metal objects, such as wires, bars, pipes or any other elongated elements.

During continuous galvanising of a steel strip, the steel strip is continuously passed through a bath containing molten metal, normally zinc, or an alloy of zinc and aluminium, a so called galvalun process. In the bath, the strip normally passes beneath a submerged roll and then moves upwardly through stabilising and correcting rolls. The strip emerges from the bath and is transported through a set of gas knives, which blow the excess zinc off the strip and back down to the bath, thus controlling the coating thickness. The gas ejected by the knives may be air, nitrogen, steam or an inert gas, but air and nitrogen are

most commonly used. The strip is then transported unsupported until the coating has cooled down and is solidified. The coated steel strip is then guided or directed via a top roll to an arrangement for cutting the strip into separate strip elements or winding the strip onto a roll. Normally, the strip moves in a vertical direction from the submerged roll through the correcting and stabilising rolls and the gas knives to the top roll.

When galvanising steel strips, it is aimed at an even and thin coating thickness. The coating mass is normally measured after the strip has passed around the top roll, and this reading is used to control the gas knives and hence regulate the coating thickness. However, due to the geometry of the steel strip, the distance the strip has to run unsupported, its speed, and the blowing action of the gas knives, the steel strip will move or vibrate in a direction generally perpendicularly to its transportation direction. Certain measures, such as the use of the correcting and stabilising rolls, a precise control of the gas flow from the gas knives, and an adjustment of the steel strip speed and/or an adjustment of the distance over which the strip has to run unsupported, may be taken in order to reduce these transverse movements. If not reduced, these transverse movements will significantly disturb the precise wiping of the gas knives, resulting in an uneven coating thickness.

A higher strip speed as well as an accurate and precise wiping of excessive coating material is required. However, the gas pressure from the gas knives has to be increased as the speed of the strip is increased. Such a pressure increase will result in sputtering of the molten coating and air turbulence problems at the edge of the strip. This means that there is a clear upper limit to the maximum strip speed when gas knives are used. Moreover, such gas knives are very noisy.

To solve these problems, it has been proposed to combine or replace the gas knives with a magnetic wiping device. The magnetic wiping device generates an alternating magnetic field which is used to wipe off excessive coating from the metal strip. Thereby, it may be dispensed with the gas knives or the gas pressure from the gas knives may be lowered while, at the same time, the same or even a better wiping effect is accomplished. The use of the magnetic wiping device helps to make it possible to increase the strip speed while maintaining an accurate and exact wiping off of excessive coating.

US-A-4 273 800 discloses such an electromagnetic wiper device for controlling the thickness of a deposited metal coating on a running metal strip. The excessive molten metal is wiped off from the strip by applying a pulsating or alternating magnetic flux to produce a flux in a looped path through the coating.

One problem connected with such magnetic wiper devices is that the magnetic forces acting on the metal strip, when the strip is not perfectly centred, tend to attract the magnetic strip towards the wiping coil. Consequently, the use of a magnetic wiper device may cause oscillation of the metal strip running from the bath to the top roll.

US-A-4 655 166 discloses an arrangement for galvanising a metal strip, wherein air knives are provided for removing recesses molten metal from the strip. The arrangement includes an electromagnetic device for preventing oscillations of the running metal strip. The electromagnetic device includes permanent magnet units arranged in the vicinity of two opposite side edges on the running strip. Detectors are provided to detect the gap between the side edges and the respective magnet unit. In order to maintain

the size of the gap at a determined level, control motors are provided to adjust the position of the magnet units in response to the detected gap.

SUMMARY OF THE INVENTION

The object of the present invention is to reduce oscillations of a running metal strip and to stabilise the position of the metal strip. More specifically, the purpose of the invention is to stabilise a metal strip in connection with the use of a magnetic wiper device for wiping off excessive molten metal from the strip.

This object is obtained by the method initially defined, which includes the steps of:
transporting the metallic object from said arrangement in a transportation direction along a transportation path including a plane,
wiping off excessive molten metal from the object by applying a magnetic force to the object, and
stabilising the position of the object with respect to the plane by applying a stabilising magnetic force to the object.

By this method, the gas knives previously used may be dispensed with, and an electromagnetic wiper device may be operated to provide a highly efficient wiping off action, since the metal object is stabilised by the magnetic force which may be applied by means of an electromagnetic stabilising device.

According to an embodiment of the invention, the method includes the steps of: sensing the value of parameter depending on the position of the object with respect to the plane, and applying said stabilising magnetic force to the object in response to the sensed value, wherein the magnetic

force includes at least a force component directed transversely to the transportation direction and transversely to the plane. In such a way, it is possible to obtain a proper positioning of the object with respect to the plane so that the object runs along the plane in a stable manner.

According to a further embodiment of the invention, the method includes the step of: applying a voltage to the electromagnetic stabilising device in response to said sensed value, thereby generating said magnetic force. Thereby, the stabilising electromagnetic force may be applied by applying voltage pulses to a winding of a stabilising pole adjacent to the plane. Preferably, said sensing step includes sensing of the level of the electric current through the winding.

According to a further embodiment of the invention, said application step includes increasing of the magnetic force when the level of the current through the corresponding winding increases. The current through the winding will increase when the magnetic reluctance of the magnetic flux circuit increases, i.e. when the distance from the stabilising poles to the metal object increases.

According to a further embodiment of the invention, said application step includes applying of said voltage in the form of voltage pulses having a substantially constant amplitude, and varying the magnetic force of the electromagnetic stabilising device by varying the length of the voltage pulses. Furthermore, said sensing step may include sensing the level of the current through the winding of a stabilising pole provided on one of said sides of the plane and sensing the level of the current through the winding of a stabilising pole provided on the other side of the plane, wherein said current levels are compared and the

length of the voltage pulses through the winding of the stabilising pole having the highest current level are increased.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be explained in more detail with reference to different embodiments, disclosed by way of example only, and with reference to the drawings attached hereto.

Fig 1 discloses schematically an arrangement for applying a coating to a running metal strip.

Fig 2 discloses an electric circuit for an electromagnetic stabilising device of a device for controlling the thickness of the coating on the metal strip according to an embodiment of the present invention.

Fig 3 discloses an electric circuit for an electromagnetic stabilising device according to another embodiment.

DETAILED DESCRIPTION OF VARIOUS EMBODIMENTS OF THE INVENTION

The arrangement disclosed in Fig 1 includes a container 1 arranged to contain a bath of molten galvanising metal, such as zinc or an alloy of zinc and aluminium, to be deposited onto a metal strip 2 running through the bath in the container 1. The metal strip 2 is transported through the container 1 by means of a roll 3 provided in the container 1 to redirect the metal strip 2 from a downward direction to a substantially vertically upwardly directed transportation direction 4 along a transportation path between the roll 3 and an upper roll 5 arranged to redirect the metal strip 2. The transportation path between the roll 3, 5 includes a substantially vertical plane x. After the upper roll 5 the metal strip is wound onto a roll 6 or cut into strip elements. It is to be noted that further stabilising or

correcting rolls may be provided to guide the metal strip 2. However, in order to make the embodiment more illustrative such possible rolls are not disclosed in the figures.

From the surface 7 of the galvanising metal bath in the container 1 the metal strip 2 runs generally unsupported all the way to the upper roll 5. As the metal strip 2 leaves the bath in the container 1 it is coated with molten galvanising metal, such as zinc, from the bath. At a predetermined distance from the surface 7 a device 8 for controlling the thickness of the coating on the metal strip 2 is provided. After the device 8, seen in the transportation direction 4, there are provided elements 9 for cooling the coating before it reaches the upper roll 5. Thereby, the coating will be solidified before the metal strip 2 is redirected by the upper roll 5.

The device 8 for controlling the thickness of the coating is disclosed more closely in Figs 2 and 3, and includes an electromagnetic wiper device 11, 12, arranged to wipe off excessive molten metal from the metal strip 2 by applying a magnetic force onto the strip 2, and an electromagnetic stabilising device 13, 14, arranged to stabilise the position of the metal strip 2 with respect to the plane x. The electromagnetic wiper device includes a first pair of wiping members 11, 12 including a first wiping member 11 on one side of the plane x and a second wiping member 12 on the other side of the plane x. Each wiping member 11, 12 may include a number of wiping poles 11a and 12a, respectively. The electromagnetic stabilising device includes a pair of electromagnetic stabilising members 13, 14, including a first stabilising member 13 on one side of the plane x and a second stabilising member 14 on the other side of the plane x. Each stabilising member 13, 145 may include a number of stabilising poles 13a, 13b and 14a, 14b, respectively.

The electromagnetic wiping members 11 and the electromagnetic stabilising members 13 on one side of the plane x have a common magnetic flux carrying member 15, and thus form a common electromagnetic element 11, 13, 15. In the same way, the electromagnetic wiping member 12 and the electromagnetic stabilising member 14 on the other side of the plane x have a common magnetic flux carrying member 16, and thus form a further common electromagnetic element 12, 14, 16. Each of the magnetic flux carrying members 15, 16 includes an iron core of iron plates or iron powder and is designed to provide the desired number of poles. Each stabilising pole 13a, 13b, 14a, 14b is surrounded by a winding 17 arranged to induce a magnetic flux in the electromagnetic elements 11-16. In the same way each wiping pole 11a, 12a is surrounded by a winding 18.

Furthermore, the device 8 includes a sensor in the form of sensor members 21, 22, see Fig 2, arranged to sense the value of a parameter depending on the position of the metal strip 2 with respect to the plane x. In the embodiment disclosed, each sensor member 21, 22 is arranged to sense a current level through the respective winding 17 of the stabilising poles 13a, 13b, 14a, 14b. The electromagnetic stabilising device 13, 14 is arranged to apply a magnetic force to the metal strip 2 in response to the sensed current level. The magnetic force includes at least a force component directed transversally to the transportation direction 4 and the plane x. It is to be noted that Fig 2 merely discloses sensor members 21, 22 for two stabilising poles 13a and 14a, although also the other stabilising poles may be connected to similar sensor members. The magnetic force of the stabilising poles 13a, 14a are obtained by the application of a voltage to the winding 17 of the respective pole 13a, 14a. The voltage is applied by means of a control unit 23 connected to said windings 17 for applying said voltage. The control unit 23 is arranged to increase the

magnetic force of one of the stabilising poles 13a, 14a when the metal strip 2 moves in a transversal direction away from the stabilising pole 13a, 14a. More specifically the control unit 23 is arranged to increase the magnetic force of one of the stabilising poles 13a, 14a when the level of the current through the corresponding winding 17 increases. The control unit 23 is arranged to apply said voltage in the form of voltage pulses, preferably square wave pulses having a substantially constant amplitude, and thereby vary the magnetic force of the stabilising pole 13a, 14a in question by varying the length of the voltage pulses.

Each stabilising pole 13a, 14a is arranged to induce a magnetic flux extending in a substantially closed loop. Thereby, one such loop extends mainly from the pole 13a to the metal strip 2 and in the metal strip along the plane x to the pole 13b and via the magnetic flux carrying member 15 back to the pole 13a. A corresponding loop extends on the other side of the plane x. The windings 17 of the poles 13a, 13b may be electrically connected to each other to form one winding 17. It is possible to dispense with the winding 17 of one of the poles 13a, 13b.

The control unit 23 forms a so-called DC-chopper and includes a frequency converter 24 to be supplied with a three-phase AC-voltage. In parallel to the frequency converter 24, a capacitor 25 is provided. The windings 17 of the stabilising poles 13a, 14a are also connected in parallel to the frequency converter 24 via the respective sensor member 21, 22 and a respective parallel-circuit including a diode 26, 27 and a switch 28, 29. Furthermore, the control unit 23 includes a processor 30, which is connected to the sensor members 21, 22 and the switches 28, 29.

The device 8 operates in the following manner. The sensor member 21 and the sensor member 22 are arranged to sense the current level through the respective winding 17. The processor 30 is arranged to receive the sensed level from the sensor members 21, 22, and to initiate switching of the switches 28 and 29 between an open state, see switch 28, and a closed state, see switch 29. By closing the switch 28, 29, a voltage will be applied to the respective winding 17. Consequently, the processor 30 will apply voltage pulses to the windings 17 of a certain length, which pulses induces a current in the respective winding 17. By means of the sensor members 21, 22 the current level through the windings 17 is measured. The current level depends on the magnetic reluctance of the respective magnetic flux circuit. If the distance between the metal strip 2 and one of the poles 13a, 14a increases, also the magnetic reluctance of the magnetic flux circuit increases, which means that the current through the winding 17 will increase since the magnetic reluctance of the magnetic flux circuit is reciprocally proportional to the current through the winding 17.

As appears from Fig 3, the device according to the invention may be provided with sensor members of another type than those disclosed in Fig 2, for instance position sensors mounted to the respective stabilising pole 13a, 14a. As in the previous embodiments the sensor members 21, 22 are connected to the processor 30. It is to be noted that any kind of proximity sensors or possibly mechanical sensors sensing the position of the strip 2 by contact may be employed in the device according to the invention.

The present invention is not limited to the embodiment disclosed but may be varied and modified within the scope of the following claims.

It is to be noted the more than one device 8 may be provided along the transportation path. Especially, when the strip 2 has a width exceeding a certain value, two devices 8 may be provided along the width of the strip 2.

Claims

1. A method for controlling the thickness of a galvanising coating on a metallic object, said coating being applied by continuous transportation of the object through an arrangement for depositing a molten galvanising metal onto the object, the method including the steps of:

transporting the metallic object from said arrangement in a transportation direction along a transportation path including a plane,

wiping off excessive molten metal from the object by applying a magnetic force to the object, and

stabilising the position of the object with respect to the plane by applying a stabilising magnetic force to the object.

2. A method according to claim 1, including the steps of:

sensing the value of parameter depending on the position of the object with respect to the plane, and

applying said stabilising magnetic force to the object in response to the sensed value, wherein the magnetic force includes at least a force component directed transversely to the transportation direction and transversely to the plane.

3. A method according to claim 2, including the step of:

applying a voltage to the electromagnetic stabilising device in response to said sensed value, thereby generating said magnetic force.

4. A method according to claim 3, wherein the stabilising electromagnetic force is applied by applying voltage pulses to a winding of a stabilising pole adjacent to the plane.

5. A method according to claim 4, wherein said sensing step includes sensing of the level of the electric current through the winding.

6. A method according to claim 5, wherein said application step includes increasing of the magnetic force when the level of the current through the corresponding winding increases.

7. A method according to claim 6, wherein said application step includes applying of said voltage in the form of voltage pulses having a substantially constant amplitude, and varying the magnetic force of the electromagnetic stabilising device by varying the length of the voltage pulses.

8. A method according to any one of claims 4 - 7, wherein said sensing step includes sensing the level of the current through the winding of a stabilising pole provided on one of said sides of the plane and sensing the level of the current through the winding of a stabilising pole provided on the other side of the plane, and wherein said current levels are compared and the length of the voltage pulses through the winding of the stabilising pole having the highest current level are increased.

9. A method according to any one of the preceding claims, wherein the galvanising metal mainly consists of zinc.

10. A method according to any one of the preceding claims, wherein the galvanising metal mainly consists of an alloy of zinc and aluminium.

Fig. 1

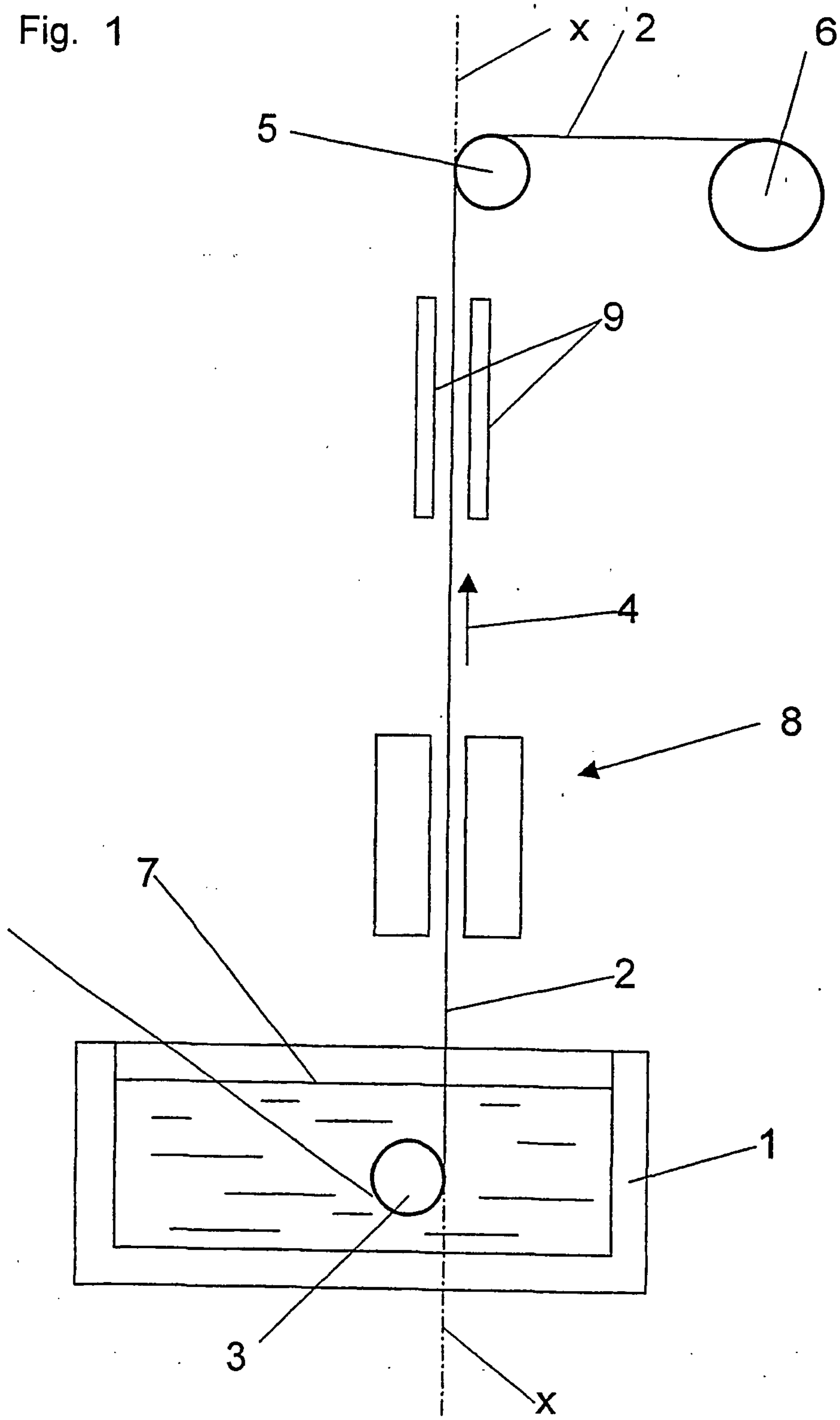


Fig 2

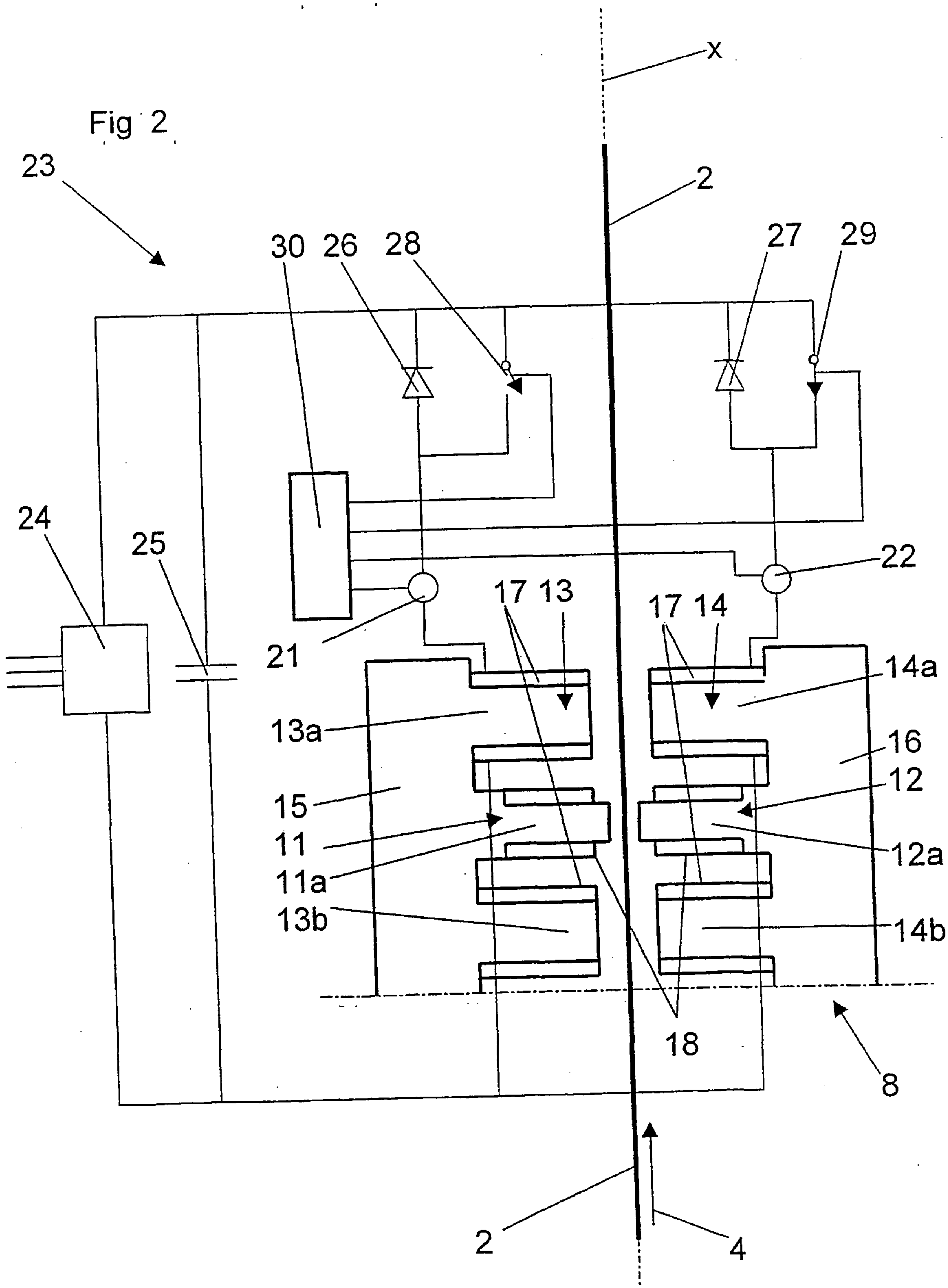
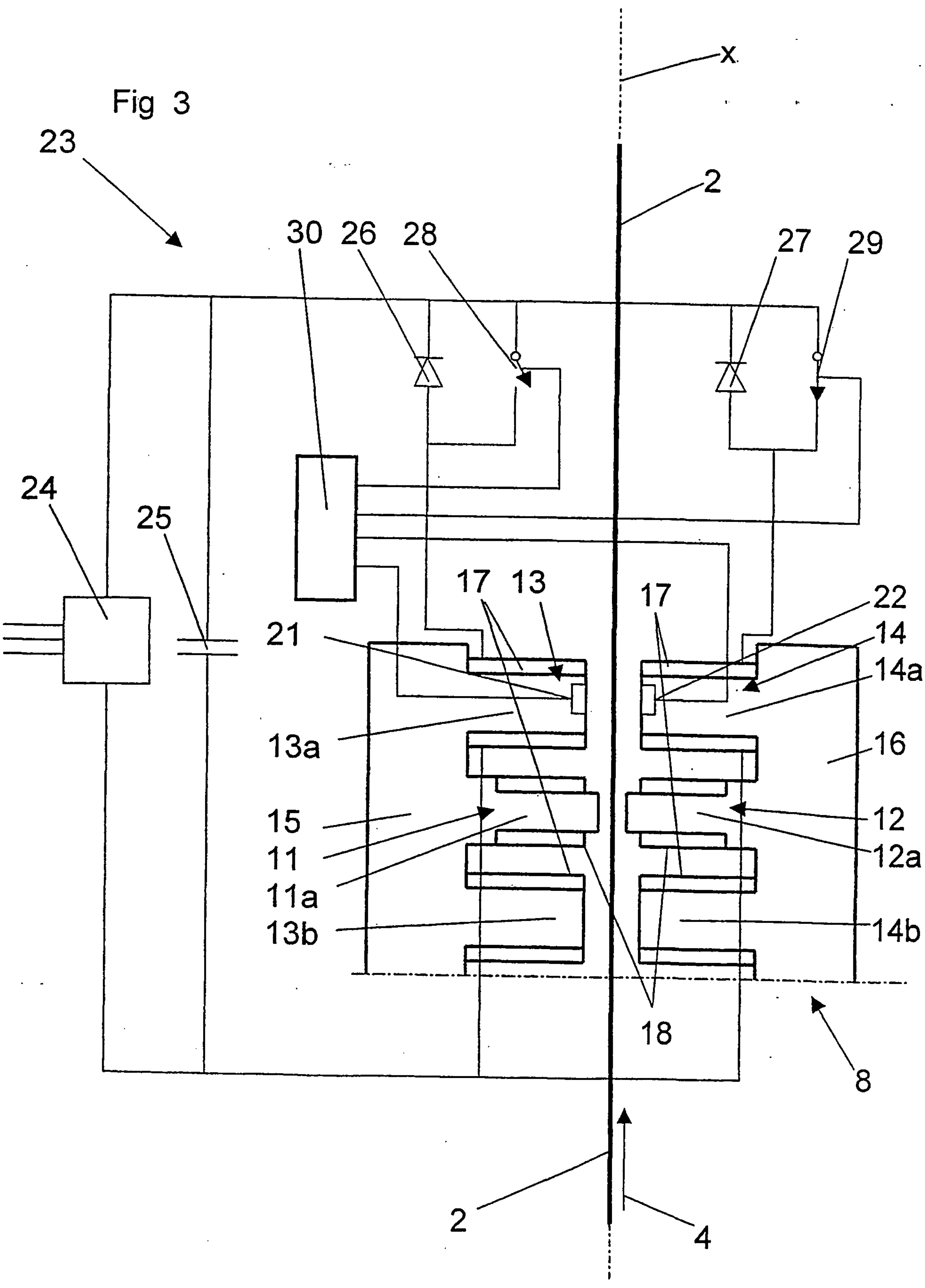

x
23
2
30 26 28
27
29
24
25
22
21
17 13
17 14
14a
13a
16
12
15
11
11a
12a
13b
14b
18
8
2
4

Fig 3


x
23
2
30
26
28
27
29
24
25
17
13
17
22
21
14
14a
13a
16
15
12
11
12a
11a
13b
14b
18
8
2
4